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Peter Bundettin

Nedical College of Waconin your Research Frit lute. Watertena Plank Rd. Lee UT 57226 (USA) The Functional Dynamics of Blood Oxygen Level Dependent Contrast in the Motor Cortex

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#### PURPOSE:

In this study, we characterize the amplitude of the oxygenation - sensitive MR signal enhancement in the motor cortex as it relates to: a) finger tapping frequency, b) on - off switching frequency, and c) duration of activation time.

INTRODUCTION:

Brain tissue T2 and T2\* values are sensitive to cerebral blood oxygenation. The MR signal enhancement in brain regions associated with specific tasks is field strength, pulse-sequence, and echo time dependent, supporting the hypothesis that the enhancement occurs as a result of a decrease in intravascular paramagnetic deoxyhemoglobin. Induced signal enhancement in the visual cortex is stimulus flicker frequency dependent - in agreement with positron emission tomography results (1). The motive of this study is to extend the understanding of the functional contrast dynamics so that a) optimal post-processing and activation timing strategies may be applied b) quantifiable correlation of MR signal enhancement with neuronal activity may be achieved.

#### METHODS:

Healthy volunteers, (ages between 26 and 31), were imaged on a 1.5 Tesla GE Signa magnet, equipped with an inserted three-axis local gradient coil of original design. A single - shot gradient - echo (TE = 40 ms, TR = 0.1 to 3 sec.) echo-planar imaging sequence (slice thickness = 2 to 15 mm, FOV = 24 cm) was used to obtain time course series of up to 1024 (64 x 64 resolution) images.

To observe MR signal dependence on tapping frequency, subjects were instructed to tap their fingers on pace with a metronome that was varied from 1 Hz to 5 Hz. To observe amplitude of signal dependence upon repetitive on-off switching frequency, subjects were cued to tap their fingers at a constant rate for on - off cycles ranging from 0.02 Hz to 0.5 Hz. The steady-state amplitude difference from the base to peak was then measured for each on - off cycle rate. To observe both the minimum activation time possible to achieve signal enhancement and the effect of long term activation, subjects were instructed to tap their fingers for durations ranging from 0.5 to 500 sec.

### RESULTS:

We find that, from 2 Hz to the maximum tapping frequency, 5 Hz, the induced MR signal change increases in an approximately linear manner. Figure 1 shows a typical relationship between signal change in the motor cortex and tapping frequency.

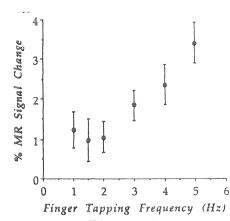
The on-off switching rate analysis is related to the desire to maximize both the induced signal amplitude and the number of activation cycles in a time course so that high quality brain activation images can be created by calculation of the cross-correlation of a reference oscillating function with the time course of each pixel (2). Figure 2, summarizing our results, demonstrates that the relative induced signal change in the motor cortex does not show a significant decrease until above a 0.06 Hz switching frequency (i.e: 8 sec "on" and 8 sec "off"), and does not follow the activation timing above 0.13 Hz. The vascular response in the brain behaves essentially as a low-pass filter in the detection of neuronal firing.

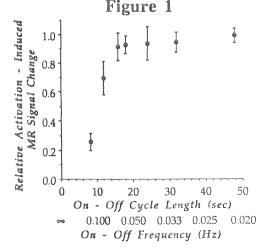
Finger movement durations as low as 0.5 sec. induce MR signal enhancement in the motor cortex after a delay of 3 sec. Also, finger movement durations of 500 sec. cause signal enhancement to plateau after 6 to 9 sec. then stay relatively constant for the remaining time.

## **CONCLUSIONS:**

Activation-induced signal enhancement in the motor cortex is finger tapping frequency dependent. On the vascular level, the implication is that, with an increase tapping frequency, the excess of oxygen delivery increases. Either more vessels dilate or the same vessels dilate more. To quantitatively correlate signal changes with neuronal activity, more needs to be understood regarding: a) the relationship between neuronal firing (number of neurons and their firing rate) and the intensity of a task, stimulus, or "cognitive load," b) the coupling mechanism between neuronal firing and vasodilatation, and c) the relationship between the induced MR signal change and vascular scale. geometry, blood oxygenation, and spatial extent of cerebral activation.

Regarding the dynamics of the induced signal change, the slow vascular response damps rapidly oscillating activations (faster than 0.06 Hz), yet, a 0.5 sec. spike of activation is followed, after a delay of 3 sec., by signal enhancement which lasts for about 3 sec.





# Figure 2

REFERENCES: 1. Kwong K.K., Belliveau J.W., Chesler D.A., Goldberg I.E., Weisskoff R.M., et al. PNAS 89, 5672 (1992). 2. Bandettini P.A., Jesmanowicz A., Wong E.C. and Hyc J.S., Magn. Reson. Med. (in press).